THE UNIVERSITY OF ALBERTA

RECALL OF MOVEMENT DISTANCE AND STARTING POSITION FROM SHORT-TERM MEMORY

by

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UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Recall of Movement Distance and Starting Position from Short-Term Memory" submitted by James Daniel McClements in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of this thesis was to analyze the effect of movement distance and starting quadrant as sources of kinesthetic information on the recall of kinesthetic information from short-term memory. There were four factors of experimental interest: sensory modality, period of delay, angular distance and starting quadrant.

The dependent variable was the absolute error between the initial trial and the reproduction trial distances. The input and reproduction trials were performed with a smoothly rotating handle. The subjects were nine university physical education students. The experimental design was a treatment by subjects, factorial, complete block, randomized repeated measures design replicated four times for each subject. A four-way analysis of variance was computed and a Duncan's Multiple Range Test was calculated for the significant main effects. A test for linearity was also calculated for the main effect of distance.

It was concluded that an increase in the distance to be reproduced caused a decrease in the performance accuracy. There was a linear relationship between the amount of error and the log (base two) of the distance. It was also concluded that the recall of visually stored information was superior to the recall of kinesthetically stored information. Due to debatable experimental technique, conclusions on the other main effects were not considered warranted.

ACKNOWLEDGEMENTS

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My love and gratitude goes to my wife,Vicki, who not only utilized visual and kinesthetic cues to type this thesis but also provided the author with the understanding, assistance and constant encouragement which enabled this author to complete this interpolated task.

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CHAPTER I

STATEMENT OF THE PROBLEM

I. INTRODUCTION

Learning the relationships of stimuli and objects in their environment is termed discriminative or perceptual learning. Perceptual motor skill learning is defined as the integration of motor skills and environmental stimuli. Environmental stimuli are transmitted within the individual (signal receiver) by sensory mechanisms. Two sensory input sources, visual and kinesthetic feedback appear to be processed in the performance of perceptual motor skills.

The stimulus or signal receiver has been likened to a "little black box" whose inner workings may be known by inference only. A few of the more highly documented (see Chapter II) mechanisms are: a long term memory (LTM), a short-term memory (STM), a motor area and a feedback system. The "little black box" has limited input capacities, limited processing speed and capacity and in certain instances, may only be able to perform one function at a time. STM can lost information through inadequate processing, recall information from LTM, utilize inappropriate expectancies or sets, and forget with STM forgetting mechanisms.

Recent findings about STM indicate that the "little black box" may have implications for the physical educator. There is evidence by Posner (1966, 1967a, b), Wilberg (1969), and Adams and Dijkstra (1966) that indicate unequal retention of visual and kinesthetic feedback in STM. As a result, there exists the possibility of more than one STM, or perhaps

one or more mechanisms for processing and/or storing information. The reason for the unequal retention has not been determined. In fact, physical educators and psychologists have not yet determined the exact nature of the information utilized from kinesthesis.

II. THE PROBLEM

Statement of the Problem

It was the purpose of this thesis to analyze the effect of movement distance and starting quadrant as sources of kinesthetic information on the recall of kinesthetic information from STM.

Importance of the Study

Implications have been made in physical education about the application of kinesthetic information to motor learning and human performance. Physical educators have only a limited knowledge regarding the probable sources, storage and utilization of kinesthetic information. Without more knowledge of these facts, any discussion of the applications of kinesthesis in motor learning would be fortuitous.

III. DEFINITIONS OF TERMS USED

Short-Term Memory

Fitts and Posner (1967) defined STM, "... as a system which loses information rapidly in the absence of sustained attention." The processes involved in STM continue only for a time interval of sixty seconds. After

this interval, the information stored in STM has been lost or has reached LTM.

Kinesthesis

Wilberg (1969) defined K, "That particular form of non-verbal information generated by the gripping and twisting of a handle."

IV. LIMITATIONS OF STUDY

Limitations

1. The structural limits of the lower arm limits axial rotation (pronation or supination) to approximately 270 degrees.

2. The replacement accuracy of the subject (the dependent variable) is measured to the nearest whole degree.

3. Subjects were selected from available college males attending the University of Alberta.

CHAPTER II

RELATED LITERATURE

Short-term memory (STM) has been extensively studied in recent years. As a result, a substantial body of knowledge regarding STM exists. However, the area of kinesthesis (K) does not appear to be as uniformly defined.

I. KINESTHESIS

Definitions

The precise nature of K is unclear. Some of the various definitions of K, used by researchers, are presented below.

McCloy (1940) defined K as, "... apparently governed by muscle-joint-sensory proprioceptive mechanisms." Day and Singer (1964) reported that recent microelectrode investigations depicted kinesthetic sense as depending solely upon joint receptors.

Gagne and Fleishman (1959) discussed K as an internal control. Young (1945) defined K as, "... the cognizance of bodily position and movements i.e. the sense of muscular effort." Witte (1952) proposed K as an individual sense of awareness of body position and parts along with the extent and force of muscular contraction. Henry (1953) defined kinesthetic adjustment as, "... the accuracy of a co-ordinated movement or muscle response controlled by afferent nerve impulses from the muscles, ligaments, tendons and joints but without the necessary implication of conscious awareness." Scott (1955) discussed K as the sense which enables us to

determine the position of the segments of the body, their rate, extent and direction of movement. Phillips and Summers (1954) defined K as, "... the conscious awareness of the individual of the position of the parts of the body during voluntary movement." Howard and Templeton (1966) defined K as, "... the discrimination of positions and movements of body parts based on information other than visual, auditory or verbal."

Wilberg (1969) commented that the attempted definitions of K, "... have not led to the establishment of a consistent definition regarding kinesthesis or kinesthetic images in memory." To circumvent this problem Wilberg (1969) established an operational definition of K for his set of experiments.

Kinesthesis and Learning

There have been several investigations of the relationship between K and learning.

From a study of rats, Honzik (1936) stated that K was essential only in the acquisition of smooth flowing movements and only after learning had begun on the basis of other stimuli. Phillips (1941) reported that there was a low positive relationship between certain phases of K and performance during the early stages of acquiring perceptual motor skills. Lafuse (1951) found no consistent differences in kinesthetic ability before and after a training period. Roloff (1954) reported that the emphasis of K during teaching did not affect learning. Phillips and Summers (1954) found that fast learning groups had a superior kinesthetic ability when compared to slow learning groups. They also reported a relationship between motor learning and positional measures of K. There was some

evidence that K was related more to the earlier stages rather than the later stages of motor learning. Espenschade (1958) reported that blindfolded subjects, after having received verbal feedback, improved their performance on a throwing task with practise. Gagne and Fleishman (1959) suggested that in their earlier phase of learning, external cues are used. These are succeeded by the internal (K) cues. Kinesthetic ability is related to the early phases of learning and to the speed of learning. Learning, however, is not facilitated by the emphasis of K cues.

Kinesthesis and Motor Performance

Physical educators have been interested in the relationship of K with respect to performance. Phillips (1941) found a low positive relationship between K and performance during the early phases of acquiring a perceptual motor skill. Young (1945) failed to find an important correlation between selected K tests and general motor ability tests. Witte (1962) reported that there was no relationship between measures of arm positioning and a ball rolling task. Mumby (1953) found a relationship between wrestling abilities and constant muscular pressure under a changing dynamic condition. Roloff (1954) reported that a battery of kinesthetic tests was correlated with a motor ability test. Start (1964) reported that K was unrelated to a mentally practised gross motor skill.

It can be noted from above that K has been inconsistently defined. This may in part account for the incongruous conclusions of these studies.

Kinesthetic Factors

The factors involved in K have not yet been clearly defined. McCloy

(1940) listed general kinesthetic sensitivity and control as one of his proposed, "... factors in motor and athletic educability." Phillips (1941) concluded that there was no basis for the phrase, "... general kinesthetic sensitivity and control." Wiebe (1954) also indicated that there was, "... no general kinesthetic sensitivity." Scott (1955) explained, "The sensation of kinesthesis is made up of many elements or forms of response. There is little or no evidence that it might be a general capacity."

Weber (1927) reported that a distance under a greater load is, "... phenomenally equivalent to a greater distance under less load." Brown et al (1948) conducted an experiment designed to measure K limb positioning movements and found that variability increased with distance.

Henry (1953) dismissed cutaneous pressure as an important contributor to kinesthetic perception but suggested joint movement as a possible factor. Gibbs (1954) found that performance was superior for a spring loaded joystick than a free moving one. Weiss (1954) loaded Gibbs' joystick for force and distance and found that distance was a more useful cue than pressure. Weiss's study differed from Gibbs' in that the former used delayed feedback and the latter used immediate feedback. Davis (1966) studied passive movement in joint receptors and concluded that acceleration was the most likely stimulus for movement. He also noted that the most sensitive area was the normal joint position and that the starting position and the direction of movement had a bearing on this sensitivity. Laszlo (1966, 1967) found that controlling K feedback by a nerve compression block caused a greater decrement of performance than controlling the exteroceptive modalities. The effect on performance by

controlling the exteroceptive modalities is depended upon the nature of the task involved. Wilberg (1969) rejected perceptual pressure (torque) as useable information in K. The exact factors contributing to kinesthetic information have not yet been adequately defined.

Inter and Intra-individual Differences

Witte (1952) found no difference between primary school males and females in kinesthetic perceptivity. Wiebe (1954) reported that there was a kinesthetic difference in favor of varsity athletes over non-athletic college men. Phillips and Summers (1954) reported that the preferred arm was superior to the non-preferred arm in familiar activities. Churchill (1965) stated that performance was equivalent for right and left hands. It, therefore, can be concluded that there are inter-individual differences in kinesthetic abilities. However, the evidence of intra-individual differences is contradictory.

II. SHORT-TERM MEMORY

General

A STM assumption is one in which the perception of a stimulus leaves a distinct after-effect which will fade or decay rapidly without rehearsal or repetition. The amount of recall will depend on the state of the decay. Hebb (1949) discussed two forms of traces, a temporary activity trace and a more permanent structural trace. Broadbent (1958) presented evidence for a recurrent system (similar to Hebb's activity trace) which accounted for short-term or immediate memory and a long term memory, each

having their own properties (Hebb's structural trace).

Posner (1966) proposed a memory model in accordance with evidence supporting both the decay and interference theories of STM. His model, the 'Acid Bath' view, was based on the evidence by Keppel and Underwood (1962) that there was no decay if the full processing capacity was available for rehearsal. If the amount of central processing was reduced, decrements in performance would be determined by the amount of interference among stored items.

Nature of Stored Material

Studies by Lloyd _et al_ (1960), Lloyd (1961), Reid _et al_ (1961) and Mackworth (1964) have all reported that performance was inversely related to storage load. Mortenson and Loess (1964) and Talland (1967) found that forgetting increased as the length of the task increased. Schaub and Lindley (1964), and Lindley and Nedler (1965) experimentally manipulated the recoding process and found that with efficient recoding association, the amount of recall improved presumably by increasing 'chunking'*. Mayzner and Adler (1965) found that letter frequency and organizational pattern regulated the retention of alpha-numeric material. They also interpreted this in terms of Miller's 'chunking'. Postman and Adams (1958), Peterson and Peterson (1962), Deese (1959, 1960), Schaub and Lindley (1964), and Lindley and Nedler (1965) used associational indexes and/or levels of meaningfulness and all reported that increases in association and meaningfulness improved performance.

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* The concept of information chunking is described by C.A. Miller in his article, "The Magical Number Seven, Plus or Minus Two," _Psychological Review_, 63, 81-97, 1956.

In summary, if the full central processing is not available then performance would be dependent, at least in part, upon the task length, the interference effect of the storage load, meaningfulness, association and recoding ability.

Proactive Inhibition

As well as intra-trial interference there is evidence of inter-trial interference. Peterson and Peterson (1959) and Murdock (1964) found little evidence for proactive inhibition (PI). PI is interference of previous learning on recall.

Conrad (1959) found that forgotten digits were replaced by digits of the same serial position in previous lists. Keppel and Underwood (1962) found a performance decrement in the later trials of a series of similar trials. Wickens *et al* (1963) found that in a series of trials if the type of material was switched the probability of an error on the first trial was greatly reduced. These results provide evidence for PI.

Loess (1964) concluded that one of the causes of forgetting using the Peterson and Peterson technique was PI. Cochran (1967) stated that PI items produced increases in forgetting. Loess and Waugh (1967) varied the inter-trial interval and found that PI decreased as the inter-trial intervals increased. PI was thus negligible when the inter-trial interval exceeded two minutes. Thus interference may be caused by PI.

Visual Images

The amount of recall is also limited by the amount of information input. Sperling (1960), utilizing a partial matrix report technique,

concluded that the immediate visual storage mechanism held more information in immediate memory than had been indicated by previous memory span experiments. He found that the amount of information available was dependent upon the amount of input. This information decayed rapidly after one-quarter second so that at one second it approached the length of the memory span. Averbach and Coriell (1961) used a technique similar to Sperling's (1960) and obtained similar results. They concluded, "The visual process involves a buffer storage whose read-in is very fast and read-out relatively slow." They also included an erasure system that allowed new material to erase stored material. Mackworth (1963) studied the relationship of Sperling's (1960) visual image to immediate memory. The amount retained in immediate memory depended on the amount of preperceptual information transmitted to immediate memory. This amount is related to the type of material, the length of the individual's memory span and the rate of reading. However, Erickson and Steffy (1964) failed to obtain any evidence for a brief perceptual memory or storage system.

The majority of the studies reported a very brief information storage in a visual buffer. The amount of this information useable in STM is very limited.

Interpolated Tasks

Broadbent (1958) stated that the short-term storage mechanism required the central processing system to prevent forgetting. If an interpolated task (IT) required some of the limited central processing capacity, an information loss occurred. Poulton (1953) found that recall was an active process which interfered with the memorization of new

material. Brown (1958), using lists well within the memory span, reported considerable forgetting over a period of several seconds if rehearsal was prevented. Conrad (1958, 1960) and Mortenson and Loess (1964) used a very brief IT (the word zero) to initiate the recall. This brief task caused the same decrease in recall as a delay filled by an IT. Peterson and Peterson (1959, 1962) reported that recall decreased with the duration of the IT activity. Posner and Rossman (1965), D'Andrea (1966), and Posner and Konick (1966a), all found that forgetting increased with the period of delay filled with an IT.

Sanders (1961) and Pollack (1963) both reported that the longer the interval before the start of the IT, the better the recall. Pylyshyn (1965) found that the greatest decrement in performance occurred when the IT was closest to the end of the stimulus. Talland (1967) and Pollack (1963) both concluded that the IT had an interupting effect on STM as well as limiting the central processing. Pylyshyn (1965) found very little difference when comparing control tasks and IT. He attributed this to the expectancy created in his control group.

It can be concluded that performance decreases as the duration of the IT period increases. Performance decrements have been reported for a very brief IT and from expectancy. The closer the task is to the end of the stimulus, the more forgetting occurs. An IT can affect recall in two ways: it controls central processing and it interrupts the memory trace.

Nature of Interpolated Tasks

The nature of the IT can also affect recall. Brown (1958), investi-

igating verbal recall found that more forgetting occurred with a similar verbal IT than with a dissimilar one. D'Andrea (1966) could not explain his results merely by the variation of the similarity between IT and stored material. Posner and Konick (1966a) found that the loss of information in STM increased with the similarity of stored and IT items. Taylor et al (1966) reported that performance did not decrease as the IT became more similar to stored items.

Pollack (1963) found that recall improved with fewer IT items. However, he noted that the nature of the interference caused by the IT items was more important than the delay itself. Posner and Rossman (1965) varied the difficulty and the number of the information transformations. When they held the similarity and the number of IT items constant, they found that recall was poorer with the more difficult transformations. They also found that the transformation duration affected the performance. Posner and Konick (1966a) confirmed the conclusion that the more difficult transformations produced poorer performances. Taylor et al (1966) found that the number of performance errors increased with the number of items in the IT. However, neither the IT difficulty nor the similarity to stored material affected recall. Talland (1967), using an easy IT (reading) and a more difficult IT (subtracting), concluded that the easier task caused less forgetting. The duration of the IT, similarity to stored items and difficulty must be considered if using an IT.

Rehearsal

Rehearsal is assumed to be occurring if an IT had not previously

been set. Sanders (1961) studied rehearsal by varying the amount of interference, the stimulus IT interval and the amount of free rehearsal time. He concluded from this that rehearsal strengthened the recall of verbal material. This strengthening was not attributed to rote repetition but to the assimilation of the material. Hellyer (1962) studying verbal recall reported that the amount of overt rehearsal improved performance. Waugh (1963) found that repeated presentation in the central segment of a list increased the recall probability proportionally for free recall of words. If words are repeated two or more times, the subject recalls a constant proportion of the words regardless of his attention set. D'Andrea (1966) found silent rehearsal more effective than oral rehearsal provided the recall order was reversed from the presentation order. There was no difference if there were no reversal differences. Corballis (1966) progressively increased or decreased the interstimulus intervals and found that progressive increases produced superior performance. He thus concluded that the effect of rehearsal of verbal material was cumulative. Talland (1967) reported that recall improved following a single rehearsal. He also stated that, "... repetition exerts an effect by reducing the rate of forgetting and not merely by delaying its onset."

Posner and Rossman (1965), having accepted Broadbent's (1958) view that a subject has a limited capacity for processing information, concluded that rehearsal requires a portion of this capacity. An IT monopolizes part or all of this capacity. Thus the amount of central processing capacity available for rehearsal will be dependent upon the nature of the IT.

Summary

The amount of information recalled depends on the state of decay in STM. If Posner's (1966) 'Acid Bath' view is accepted, this decay depends on the amount of interference, the amount of material input, the storage duration and the amount of central processing available for rehearsal.

III. SHORT-TERM MEMORY AND PERFORMANCE

Non-Verbal Short-Term Memory

Most of the research conducted in STM theory has used visual and auditory verbal material. Physical educators are of course, more interested in non-verbal materials. King (1965) used standard perceptual tests of brightness, flash rate, loudness, pitch and duration over temporal delays of 15, 30 and 60 seconds. He found that performances on all the perceptual tasks were stable over time delays. From these findings, he concluded that sensory storage was governed by its own consonants and, "... not by those applying to the retaining of more typical 'learned' material." Adams and Dijkstra (1966) used a linear motor distance estimation task and found that the K motor storage system lost information over time. This K loss was similar to the visual loss. They also noted these results paralleled previous verbal experiments. However, the accuracy of performance suggested the information was not stored using verbal labels. Posner (1966) and Posner and Konick (1966b) utilized a two-lever task and interpolated tasks which had different levels of difficulty. From this they found that both the visual (V) and the K information were lost over time. However, the V resting group had the best performance.

For the V IT group the level of task difficulty was inversely related to performance. For the K resting and IT groups there were no differences in performance. This lead Posner (1966) and Posner and Konick (1966b) to conclude that the V information requires the central processing system while the K information does not use this system. The authors analyzed the method of maintenance using a post test interview technique and concluded that the information was maintained by imagery and not verbal labels. Posner and Konick (1966b) further reported that the percentage loss over the first 10 seconds was 36 per cent for V and 50 per cent for K. They concluded that the V system has a greater storage capacity. Posner (1967a, b) used the two manual levers to verify that the K information was lost for both the resting and the IT conditions. However, for the V conditions, information was lost for the IT conditions but not for the resting conditions. Wilberg (1969) found a similar V and K forgetting pattern.

To summarize, the loss of simple motor information varies differently for V and K STM. The addition of a verbal IT for K stored information caused no decrement in performance. However, the verbal IT caused a decrement to visually stored motor information. Recall of non-verbal information is too accurate to be stored by verbal labels, thus, it must be stored by imagery. Also V input information is recalled better than K input information.

Motor Interpolated Tasks

A verbal IT affects the V STM differently than K STM. The effect of a non-verbal IT is also relevant. Bilodeau and Ryan (1960) reported that

the effect on recall of an IT of maintaining the arm steady was not different from resting for a line drawing task. Blick and Bilodeau (1963) found that a similar IT of circular rotation did not affect the retention or learning of an arc reproduction task. Boswell and Bilodeau (1964) found that the IT of picking up a pencil disturbed retention more than zeroing the task lever over a 28-second interval. Posner and Rossman (1965) found that the amount of V forgetting was a direct function of the difficulty. Therefore, it is only reasonable to conclude that the more difficult motor IT will cause a loss of information and easier tasks will not cause a loss.

Short-Term Memory and Kinesthesis

Studying K using STM procedures is the most recent approach to understanding K. The research to date is mainly exploratory in nature. Posner and Konick (1966b) and Posner (1967a, b) found that error was a linearly increasing function of the movement distance. Norrie (1968) concluded that the period of delay did not affect the reproduction of standard tension. Wilberg (1969) rejected K input of pressure as a source of useable information in a replacement task. Carre (1969) and Moyst (1969) used identical replacement tasks. Moyst (1969) rejected ballistic pressure as useable information while Carre (1969) accepted increasing torque as useable information.

All the above studies had gross body movement during the rest and immediate conditions. Posner and Konick (1966b) and Posner (1967a, b) had their subjects move from lever to lever while Wilberg (1969), Carre (1969) and Moyst (1969), all had the subjects rotate 360 degrees. If

one considers Boswell and Bilodeau's (1964) findings, these gross body movements may in fact be interpolated tasks. However being exploratory studies, the most important findings are those on the dependent variable. To date ballistic pressure and pressure have been rejected while distance and increasing torque have been accepted as sources of useable information in K.

IV. SUMMARY

The term K has been used in physical education for several decades. Although there have been many studies on K, it has not been uniformly defined. A new avenue of K research has been developed from Posner's (1966) and, Posner and Rossman's (1966) reports that interpolated tasks affect V and K STM differently. The studies utilizing this approach have been exploratory in nature. An adequate definition of K is essential before research can be conducted on K's role in motor learning and motor performance.

CHAPTER III

PROCEDURES

I. EXPERIMENTAL DESIGN

The experimental design was a treatment by subjects, factorial, complete block, randomized design with repeated measures. The design was replicated four times for each subject.

There were four factors of experimental interest: sensory modality, period of delay, angular distance and initial starting quadrant. The sensory modality factor had two levels: (visual (V) and kinesthetic (K)). The remaining three factors each had three levels: period of delay (immediate, 10-second delay and 10-second delay with an interpolated task), distance (30, 60 and 120 degrees), and starting quadrants. (See Figure 1.) The movement distances all began and ended randomly in the quadrants described in Figure 1. Mechanical limitations of the arm necessitated the omission of quadrant four.

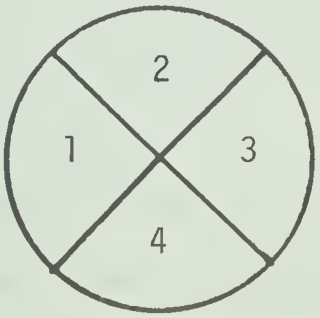

FIGURE 1

STARTING QUADRANTS

II. APPARATUS

The apparatus utilized was a smoothly rotating handle. The pivot (spindle) of the handle passes through the back of a 24 inch by 24 inch by 16 inch hollow box. (See Figure 2.) A metal disc was attached to the spindle. The smallest measurement recordable on the circumference of the disc was one degree.

For the initial or input trial a self-closing electrical circuit closed after the handle was twisted the required distance. When this circuit was closed a signal tone was produced from a pure tone generator. An EICO model 377 auditory tone generator was connected to a Bogen 'Challenger' model CHB20A amplifier, a four inch speaker and a Hunter Decade Interval Timer model 111B. The 10-second period of delay was timed by a GraLab Universal Timer model 172, which sounded its own buzzer at the end of the delay. A sight was attached to aid the taking of the readings on the disc at the start and the completion of the reproduction trial.

The visual cues were eliminated by a pair of commercial ski goggles made opaque by fixing paper to the lens.

III. INTERPOLATED TASK

The interpolated task (IT) was a circular, hand, binary decision maze task. Three sets were constructed out of plywood, plexiglass and a nail. (See Figure 3.) The sensory modality cues were identical to the experimental conditions. The decisions were visually or kinesthetically made using the same apparatus. There was no preview, as the top only

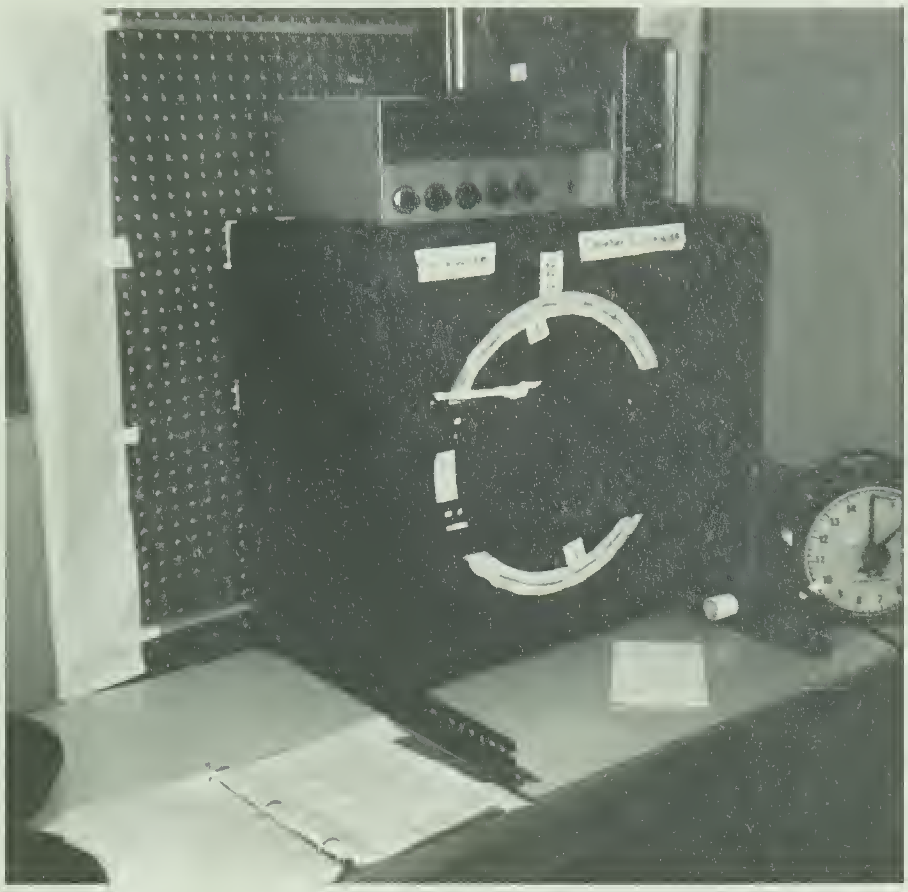

FIGURE 2

REAR VIEW APPARATUS

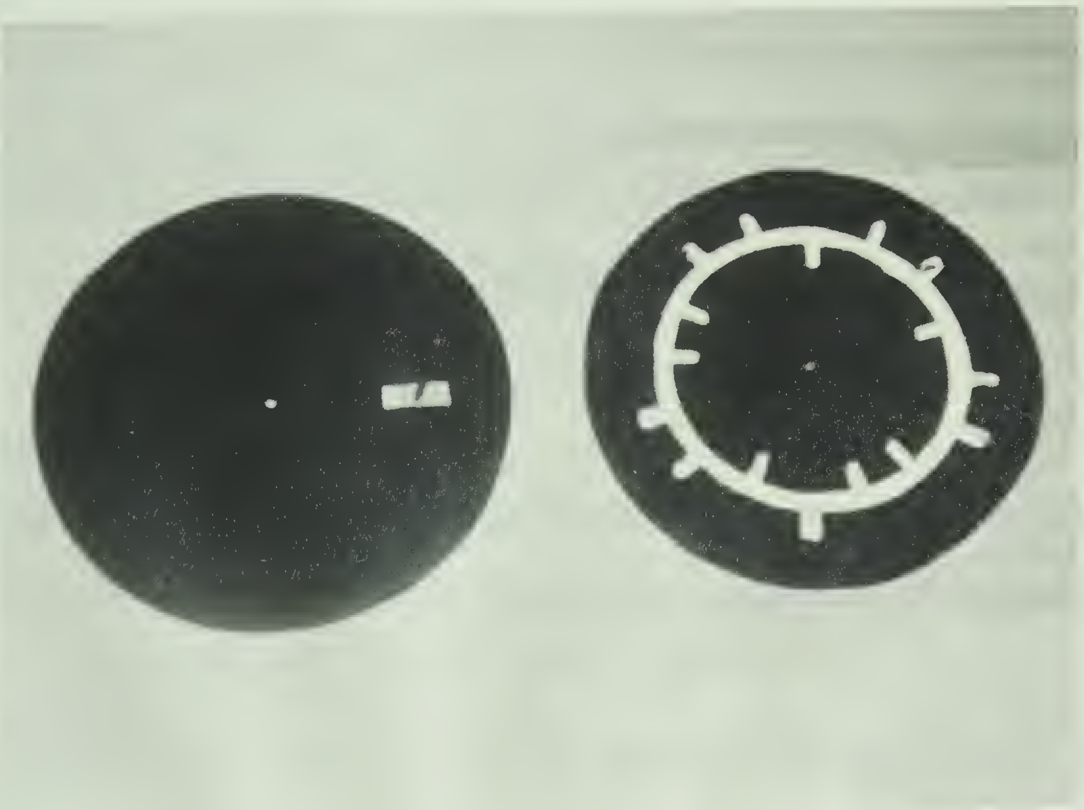

FIGURE 3

INTERPOLATED TASK APPARATUS

allowed viewing of one decision at a time. The decision was basically of a binary (in-out) nature.

IV. SUBJECTS

The experiment required nine subjects. These subjects were male university physical education students between the ages of eighteen and twenty. The subjects were selected on the basis of availability and freedom from physical handicaps which could interfere with their performance.

V. METHOD

The subject was positioned on a chair facing the apparatus. When the subject grasped the handle he always used his preferred hand and always placed his forefinger at the same end of the handle.

There were four phases to every trial: an instruction phase, an input phase, a storage phase and an output phase.

Instruction Phase

Before each trial the subject was presented with a series of instructions. These instructions were about the sensory modality, the period of delay and the direction the handle was to be twisted. For the sensory modality, the subject was asked to wear the goggles (if the sensory modality was K) or not to wear the goggles (if the sensory modality was V). For the period of delay, the subject was asked to regrasp the handle

immediately, after a 10-second delay or after a 10-second interpolated task. (See storage below.) The direction of the handle was either clockwise or counter-clockwise and was determined randomly.

Input Phase

After receiving the instructions the subject either wearing or not wearing the goggles grasped the handle in its initial starting position, twisted it until he heard a signal tone. The initial starting position and the angular distance the handle was twisted were the nine combinations of the three starting quadrants and the three distances (30, 60, 120 degrees). After hearing the tone the subject released the handle.

Storage Phase

The subject had been instructed to do one of the three following things:

immediate - The subject released the handle and almost immediately regrasped the handle.

resting - The subject released the handle and rested for 10 seconds. Then on an auditory signal the subject regrasped the handle.

interpolated task - The subject released the handle and immediately started working at the IT for 10 seconds. The object of the IT was to make as many decisions as possible. After 10 seconds on an auditory signal, the subject regrasped the handle.

Output Phase

During the storage phase the experimenter randomly positioned the

handle to a reproduction trial starting position. The subject grasped the handle at the end of the storage period and attempted to reproduce the distance moved during the input phase.

The subjects' score for each trial was the absolute difference between the input distance, determined by the experimental condition and the reproduced output distance.

VI. STATISTICAL ANALYSIS

A four way analysis of variance (ANOVA) was selected for the statistical analysis. A Fortran IV ANOV80 program (a N-way analysis of variance program which utilizes the IBM Scientific Subroutine Package) was obtained from the Department of Educational Research. The program was computed on the IBM 360/67 computer at the University of Alberta Computing Science Department.

An $\underline{F}$ ratio and a Duncan's Multiple Range Test were used as tests of significance on the main effects. A stringent test was necessary to decrease the probability of an alpha or Type 1 error. The rejection level was set at $\alpha = 0.01$.

CHAPTER IV

ANALYSIS

I. HYPOTHESES

Four hypotheses were formed from the review of literature:

1. H_1: Immediate errors $\leq$ 10-second delay errors < 10-second delay with interpolated task errors.

2. H_2: Visual < Kinesthetic.

3. H_3: 30 degrees < 60 degrees < 120 degrees.

4. H_4: Quadrant one = Quadrant two = Quadrant three.

The dependent variable for all of these four hypotheses was performance. (See note 1.) The first two hypotheses were made on the control factors of the study.

The first hypothesis stated that with a zero second delay, the performance will be less than or equal to the performance after a 10-second delay and that an interpolated task (IT) will be significantly greater than the zero and the 10-second delays ($\alpha = 0.01$). The second hypothesis stated that the visual (V) performance will be significantly less than kinesthetic (K) performance ($\alpha = 0.01$). The interaction between the period of delay and the sensory modality is of more importance.

Studies by Posner (1966, 1967a, b) and Posner and Konick (1966b) concurred that K information was lost during the delay period while V

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[1] Performance was measured by absolute error between the initial trial and the reproduction trial. There is a difference between performance and forgetting which Posner (1967a) discussed.

information was not lost. Wilberg (1969) and Moyst (1969) reported no difference between V and K performance.

Hypothesis three was formed on the basis of Posner (1966, 1967b) and Posner and Konick's (1966b) conclusions that performance was inversely related to movement distance. The distances were selected to facilitate a test of linearity between distance and absolute error (distance = 30 degrees ($\log_2 Y$) where Y = 1, 2, 3).

Hypothesis four was stated in the null form because it was purely exploratory in nature. Davis (1966) did note that the most sensitive area was in the normal joint position; however, this statement was not conclusive.

II. RESULTS

A four-way analysis of variance was calculated and is summarized in Table 1. The main effects of modality (F = 20.150) and distance (F = 55.053) were significant at the $\alpha = 0.01$ level. Starting quadrant (F = 3.138) was significant at the $\alpha = 0.05$ level, however, an $\alpha = 0.01$ had been decided <u>ad hoc</u> for the rejection level.

A Duncan's New Multiple Range test was performed on the K = 3 means of the significant main effect of distance (Table 2). The absolute mean error was significantly greater for each increment of distance ($\alpha = 0.01$). The relationship between distance and absolute error was tested for linearity (Table 3). This relationship was significant and the deviations from linearity were not significant ($\alpha = 0.01$).

A six-way analysis of variance was computed to evaluate the main

TABLE 1

FOUR WAY ANALYSIS OF VARIANCE

Source	df	Mean Squares	F
Modality (MOD)	1	3,678.914	20.150**
Period of Delay (STM)	2	119.668	0.655
MOD x STM	2	15.879	0.087
Distance (DIST)	2	10,051.512	55.053**
MOD x DIST	2	441.144	2.416
STM x DIST	4	60.387	0.331
MOD x STM x DIST	4	339.417	1.859
Quadrant (QUAD)	2	572.977	3.138*
MOD x QUAD	2	427.521	2.342
STM x QUAD	4	243.189	1.332
MOD x STM x QUAD	4	242.343	1.327
DIST x QUAD	4	129.149	0.707
MOD x DIST x QUAD	4	84.470	0.463
STM x DIST x QUAD	8	155.890	0.854
MOD x STM x DIST x QUAD	8	246.004	1.347
ERROR	1404	182.578	

CRITICAL F VALUES

df	.05	.01
1,1000	3.85	6.66
2,1000	3.00	4.62
4,1000	2.38	3.34
8,1000	1.95	2.53

* Significant at .05 level

** Significant at .01 level

TABLE 2

DUNCAN'S NEW MULTIPLE RANGE TEST APPLIED TO THE DIFFERENCES BETWEEN K = 3 MEANS FOR DISTANCE

	30°	60°	120°	Shortest Significant Range
Mean	10.83	14.73	19.90	
10.83		3.90**	9.07**	R_2 = 2.269
14.73			5.17**	R_3 = 2.327

** significant at the 0.01 level.

TABLE 3

TEST OF LINEARITY AND DEVIATIONS FROM LINEARITY

Source	df	Mean Squares	F
Linear Regression	1	19,972.055	109.515**
Deviations	1	230.968	1.269
Within Trials	1404	182.004	

CRITICAL F VALUE

df	.01
1,1000	6.66

** significant at .01 level

TABLE 4

EXCERPTS OF SUBJECTS AND REPLICATIONS
FROM THE SIX WAY ANALYSIS OF VARIANCE

Source	df	Mean Squares	F
Subjects	8	1230.600	8.680**
Replications	2	214.891	1.516
ERROR	128	141.769	

CRITICAL F VALUES

df	.01
2,128	4.78
8,128	2.65

** significant at .01 level

effects of subjects and replications. Subjects were a significant main effect and replications were not significant ($\alpha = 0.01$), (Table 4, Figure 4).

The means of the 54 experimental conditions are presented in Table 5. The means of the sensory modality by period of delay by distance, the sensory modality by distance, the sensory modality by period of delay interactions and the modality main effect are presented in Table 6. The sensory modality by period of delay by starting quadrant and the starting quadrant by sensory modality interaction means are presented in Table 7. The starting quadrant by period of delay interaction means, the distance by period of delay interaction means, and the period of delay, distance and starting quadrant main effects are presented in Table 8. The starting quadrant by distance interaction means are presented in Table 9.

The graphs of the sensory modality and trials main effect are illustrated in Figure 4. The graphs of the main effects of period of delay, distance and quadrant with their interactions with sensory modality are illustrated in Figures 5, 6 and 7 respectively. The graphs of distance and starting quadrant interactions with period of delay are illustrated in Figure 8. The distance by starting quadrant interaction is illustrated in Figure 9.

III. DISCUSSION

Period of Delay

Broadbent (1958) stated that short-term memory (STM) required the central processing system to prevent forgetting. If an IT required some

TABLE 5

MEANS OF FIFTY-FOUR EXPERIMENTAL CONDITIONS

Condition	Quadrant 1			Quadrant 2			Quadrant 3		
	30°	60°	120°	30°	60°	120°	30°	60°	120°
V Immediate	9.33	13.44	22.33	10.33	20.96	27.63	10.26	15.00	17.56
V Delayed	6.74	15.74	18.11	15.22	16.04	18.81	10.59	22.07	24.37
V Interpolated	12.04	15.70	20.52	16.26	16.41	24.07	11.33	14.67	26.56
K Immediate	9.48	11.96	14.11	12.19	14.04	14.63	12.19	14.00	18.74
K Delayed	8.52	12.04	15.52	8.41	10.67	21.48	11.37	11.85	19.59
K Interpolated	10.19	17.59	16.89	9.96	8.26	18.07	10.63	14.74	19.22

TABLE 6

MEANS OF THE MODALITY BY PERIOD OF DELAY BY DISTANCE, THE MODALITY BY DISTANCE AND MODALITY BY PERIOD OF DELAY INTERACTIONS, AND THE MODALITY MAIN EFFECT

	VISUAL				KINESTHETIC			
Condition	30°	60°	120°	Mean	30°	60°	120°	Mean
Immediate Recall	11.28	13.33	15.83	13.48	9.98	16.47	22.55	16.32
Delayed Recall	9.43	11.52	18.86	13.27	10.85	17.95	20.43	16.41
Interpolated Task	10.26	13.53	18.06	13.95	13.21	15.59	23.72	17.51
Mean	10.33	12.79	17.58	13.57	11.35	16.67	22.21	16.74

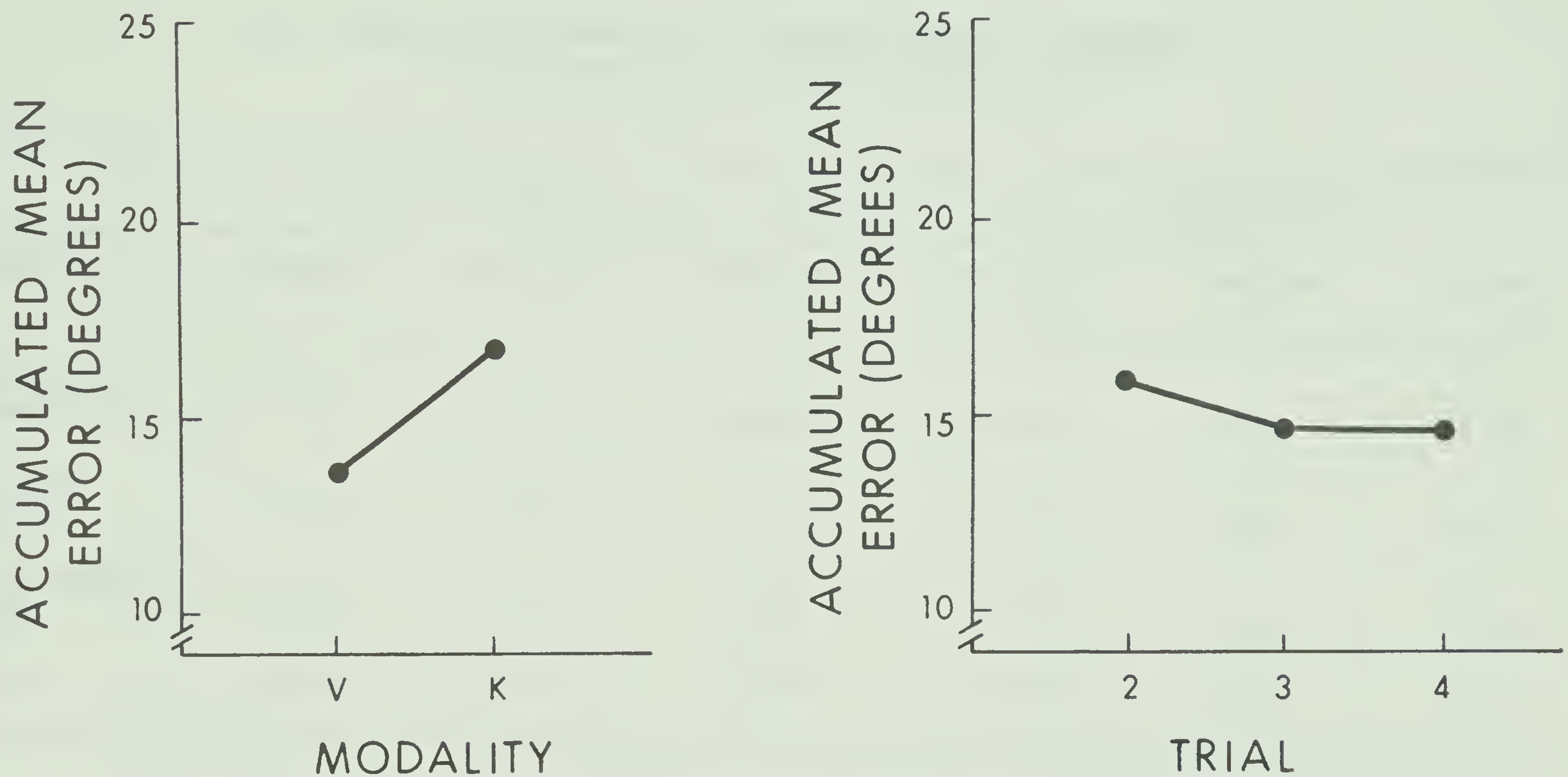

FIGURE 4

THE ACCUMULATED MEAN ERROR FOR THE MAIN EFFECTS OF SENSORY MODALITY AND TRIALS

TABLE 7

MEANS OF THE MODALITY BY PERIOD OF DELAY BY QUADRANT AND THE MODALITY BY QUADRANT INTERACTIONS

	VISUAL			KINESTHETIC		
Condition	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 1	Quadrant 2	Quadrant 3
Immediate Recall	11.85	13.62	14.98	15.04	19.64	14.27
Delayed Recall	12.02	13.52	14.27	13.53	16.69	19.01
Interpolated Task	14.89	12.10	14.86	16.09	18.91	17.52
Mean	12.92	13.08	14.70	14.88	18.42	16.93

TABLE 8

MEANS OF THE QUADRANT BY PERIOD OF DELAY AND THE DISTANCE BY PERIOD OF DELAY INTERACTIONS, THE QUADRANT, THE DISTANCE AND THE PERIOD OF DELAY MAIN EFFECT

	QUADRANT			DISTANCE			
Condition	1	2	3	30°	60°	120°	Main Effect
Immediate Recall	13.44	16.63	14.62	10.65	14.90	19.17	14.90
Delayed Recall	12.78	15.10	16.64	10.14	14.73	19.65	14.84
Interpolated Task	15.49	15.51	16.19	11.73	14.56	20.89	15.73
Main Effect	13.90	15.75	15.82	10.83	14.73	19.90	

TABLE 9

MEANS OF THE DISTANCE BY QUADRANT INTERACTION

	30°	60°	120°
Quadrant 1	9.38	14.41	17.91
Quadrant 2	12.06	14.39	20.78
Quadrant 3	11.06	15.38	21.01

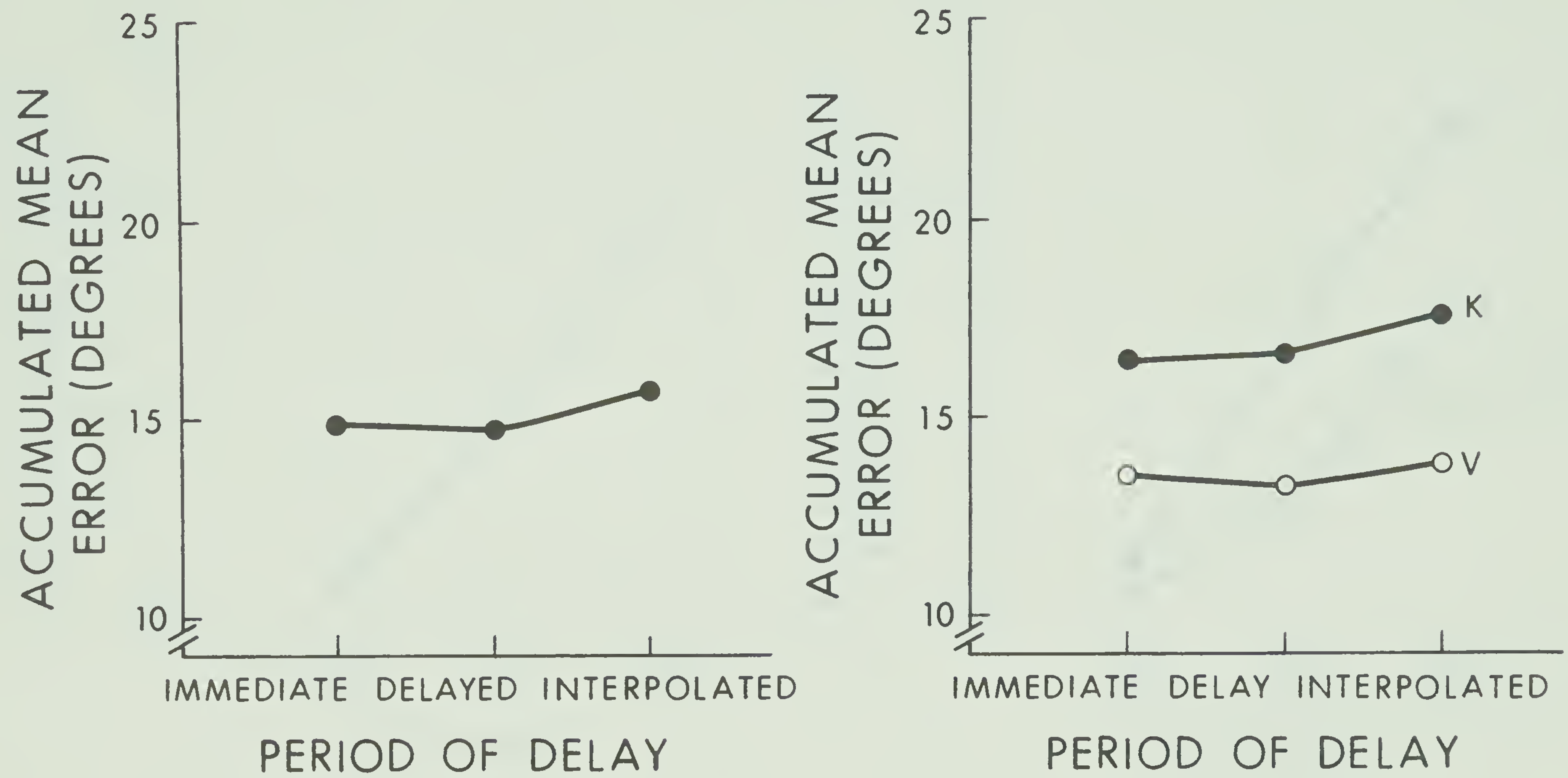

FIGURE 5

THE ACCUMULATED MEAN ERROR FOR THE MAIN EFFECT OF PERIOD OF DELAY
AND ITS INTERACTION WITH SENSORY MODALITY

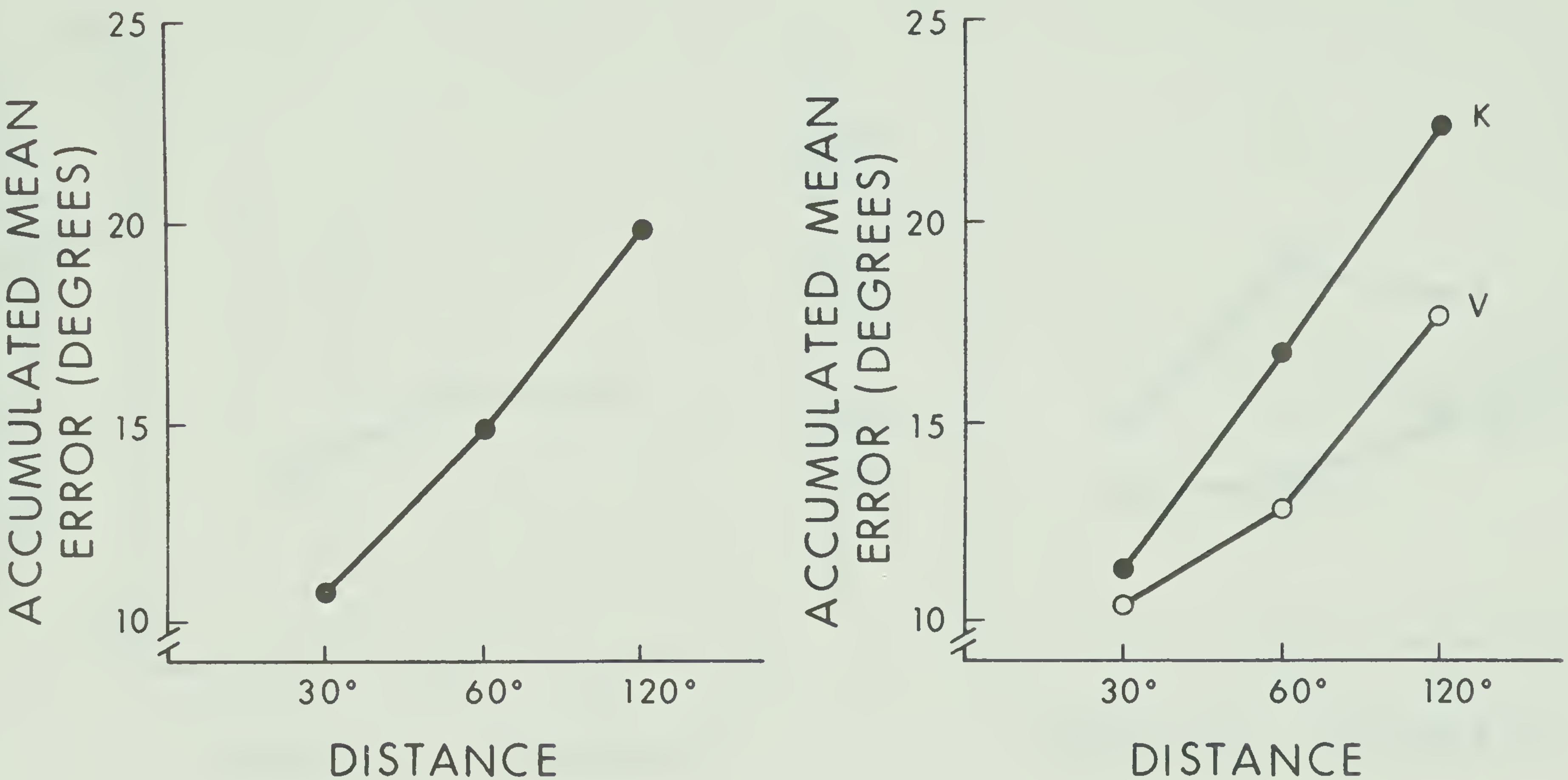

FIGURE 6

THE ACCUMULATED MEAN ERROR FOR THE MAIN EFFECT OF DISTANCE AND ITS INTERACTION WITH SENSORY MODALITY

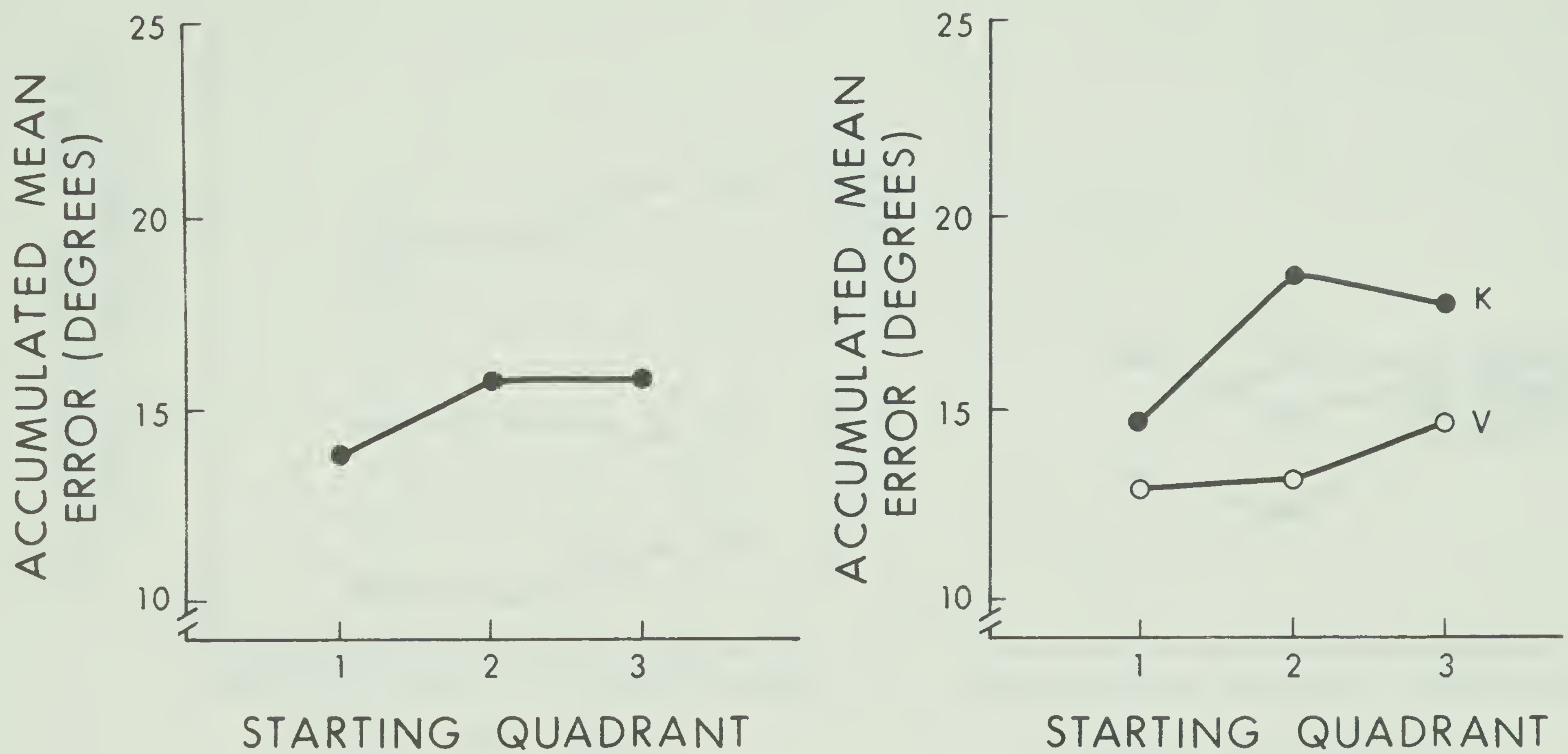

FIGURE 7

THE ACCUMULATED MEAN ERROR FOR THE MAIN EFFECT OF STARTING QUADRANT AND ITS INTERACTION WITH SENSORY MODALITY

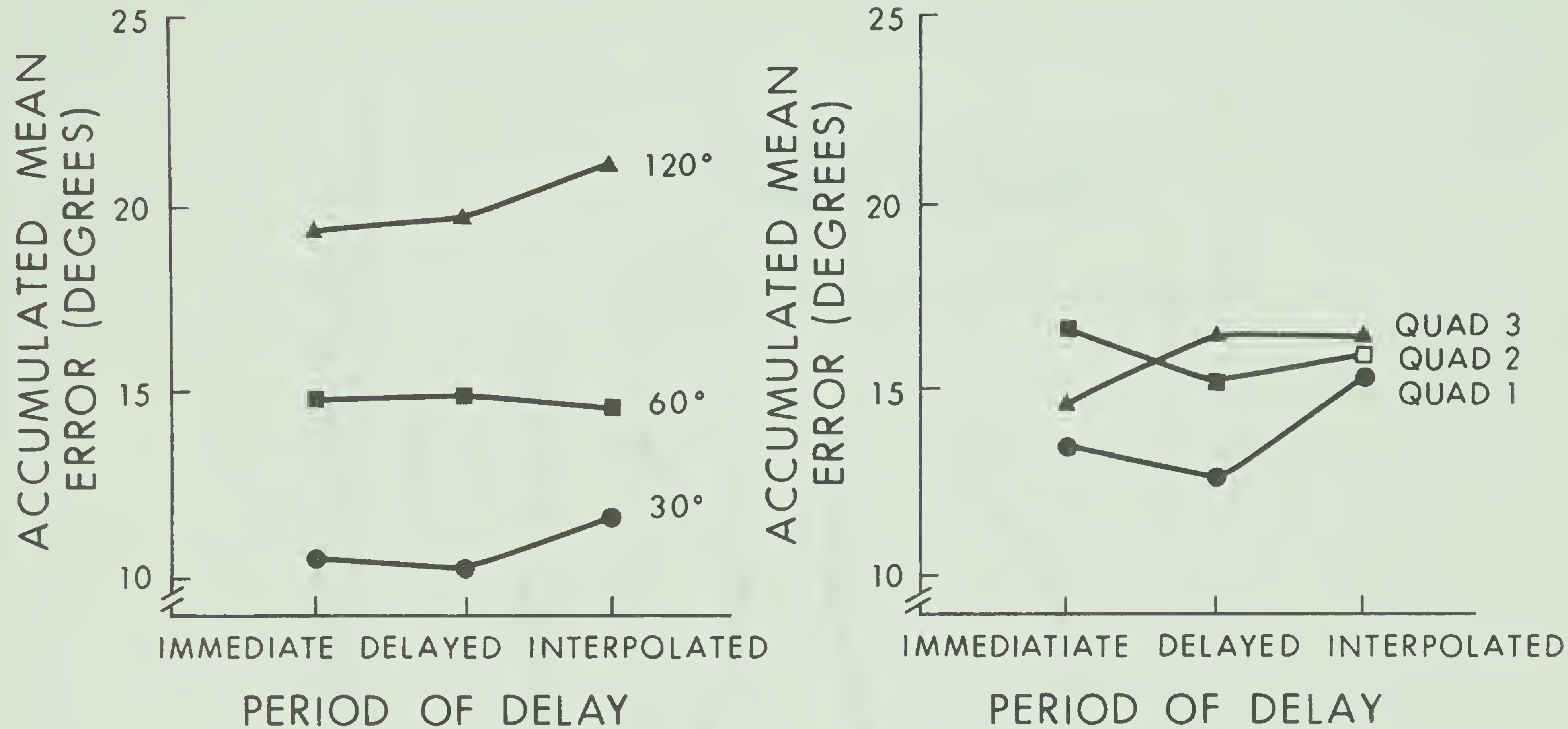

FIGURE 8

THE ACCUMULATED MEAN ERROR FOR THE PERIOD OF DELAY INTERACTIONS WITH DISTANCE AND STARTING QUADRANT

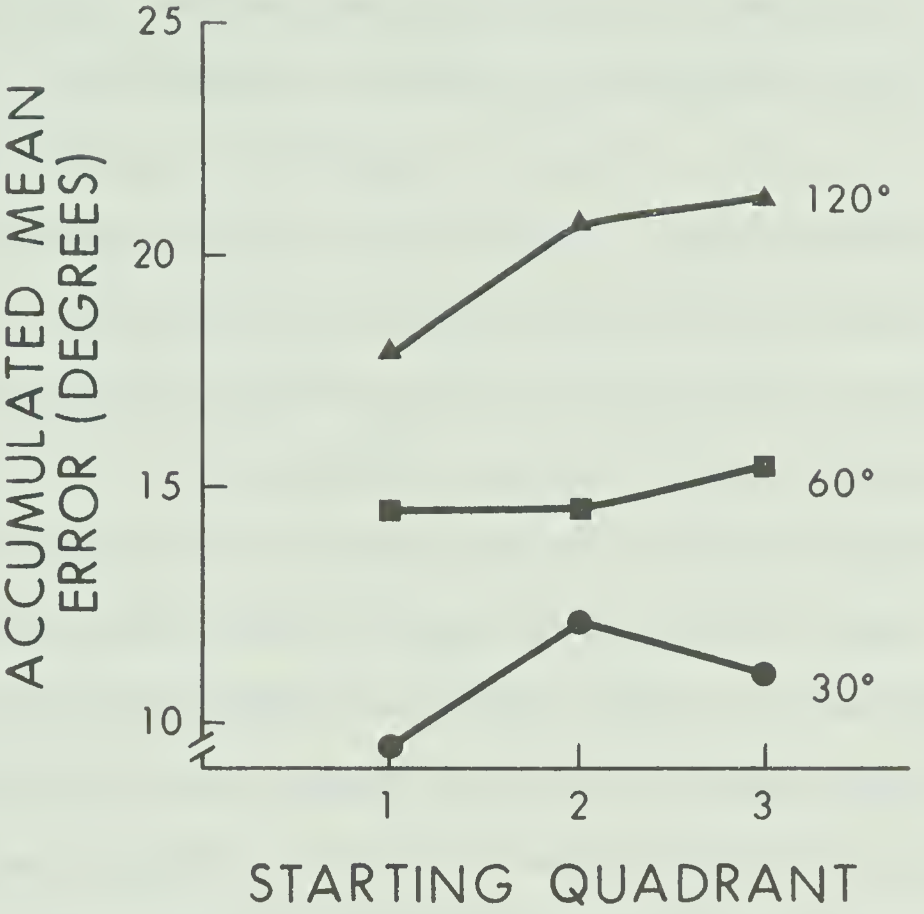

FIGURE 9

THE ACCUMULATIVE MEAN ERROR FOR THE DISTANCE BY STARTING QUADRANT INTERACTION

of the limited processing capacity an information loss occurred. Brown (1958), Conrad (1958, 1960), Peterson and Peterson (1959, 1962), Sanders (1961), Pollack (1963), Posner and Rossman (1965), Posner and Konick (1966a) and Talland (1967) all found that information was lost when the rehearsal of verbal material was controlled by a verbal IT.

In this study there was no effect on performance from a 10-second delay with or without an IT (Table 1, Figure 5). This is at variance with both the verbal and motor STM research. Adams and Dijkstra (1966) reported that forgetting occurred over time intervals without an IT. Moyst (1969) reported forgetting over a 10-second delay and more forgetting with an IT. Wilberg (1969) reported forgetting only with an IT. Carre (1969) reported no difference due to a 10-second delay or an IT. King (1965) noted that sensory storage was stable over time.

Posner and Konick (1966b) and Posner (1967a, b) reported a consistently significant sensory modality by period of delay interaction. The V condition had forgetting with the IT but no forgetting without the IT. For the K condition there was forgetting without the IT but no increased forgetting with IT activity. They interpreted this difference to mean that the V STM required the central processing system while the K STM did not require this system. These results were not borne out in this study. The sensory modality by period of delay interaction was not significant (Table 1, Figure 5). In fact, the V and K main effects are almost parallel (Figure 5).

There are two possible explanations which may account for the results of this experiment disagreeing with the literature. Bilodeau and Ryan (1963) and Blick and Bilodeau (1963) reported that the IT of main-

taining the arm steady and the circular rotation of the arm had no effect on the retention. Boswell and Bilodeau (1964) reported that a zeroing of the task lever had no effect on retention. However, picking up a pencil did cause forgetting. It could be concluded that the IT used in this experiment being motor in nature was not an IT. However, the task did involve binary decisions, which were assumed to require central processing which would qualify it as an IT.

The other explanation is a product of Pylyshyn's (1965) research where he found little difference between a control group and an IT group. He attributed this to an expectancy factor found in the control group. Other research by Pollack (1963) and Talland (1967) concluded that the IT had the effect of interrupting stored information in addition to controlling the central processing system. It is possible that when using a repeated measures design the recall decision, of which period of delay to use, could in fact be an IT itself. Poulton (1953) noted that the recall of previously learned items was an active process which interfered with the memorization of new material. The latter explanation leaves the repeated measures design a suspect for STM research.

The hypothesis formed for the period of delay (immediate error, 10-second delay error, 10-second delay with IT error) was rejected, however, the experimental design is questionable.

Sensory Modality

Raffel (1936) suggested that V and K information were stored in different projection centers in the brain. Posner and Konick (1966b) also reported that V STM may be different from K STM. Posner (1966, 1967a)

and Carre (1969) reported that V STM was equal to K STM. Posner and Konick (1966b), Wilberg (1969) and Moyst (1969), all reported that V STM was superior to K STM. Posner (1967a) reported V STM was affected by an IT while K STM was not affected. In the present experiment V STM was superior to K STM (Table 1, Figure 4). The sensory modality by period of delay interaction was not significant (Table 1, Figure 5).

These results are open to question until the IT problem discussed above is solved. However, it does seem to the author reasonable to suggest that there may, in fact be an interaction. This interaction would be at the mercy of the central processing system which in turn must not be required during the delay period only and must be required during the IT period.

The hypothesis formed for the sensory modality (V < K) was accepted, however, again the experimental technique was questioned.

Distance

The main effect of distance was significant (30° < 60° < 120°) (Table 1, 2, Figure 6). This agrees with the results of Posner and Konick (1966b) and Posner (1967b) that accuracy decreases as distance increases. The intervals were selected to facilitate a test of linearity (Table 3). There was a significant logarithmic relationship between accuracy (performance) and distance. The insignificant interactions of distance by period of delay, sensory modality and quadrant (Table 1, Figures 6, 8 and 9), allow the conclusion that the effect of distance on accuracy is independent of the sensory modality, period of delay and starting quadrant.

The hypothesis formed for distance (30° < 60° < 120°) was accepted.

Starting Quadrant

The review of literature produced only one article related to starting quadrant. Davis (1966) suggested that the normal position of a joint was its most sensitive position. This was not regarded as enough evidence to state the hypothesis in any form but the null hypothesis. This study failed to reject the null hypothesis (Table 1, Figure 7). There were no significant interactions of starting quadrant by period of delay, sensory modality and distance (Table 1, Figures 7, 8 and 9) allowing the conclusion that the effect of starting quadrant on accuracy is independent of sensory modality, period of delay and distance.

Although not acceptable in this experiment, the starting quadrant main effect was significant at the $\alpha = 0.05$ level. If a smaller portion than a quadrant had been used and these portions had been at the extremes of the subject's range of movement not quadrants, this effect may have been significant.

The fourth hypothesis of starting quadrants (quadrant one = quadrant two = quadrant three) was not rejected.

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

The purpose of this thesis was to analyze the effect of movement distance and starting quadrant as sources of kinesthetic information on the recall of kinesthetic information from short-term memory. The experimental design was a treatment by subjects, factorial, complete block, randomized design with repeated measures. The design was replicated four times for each subject. The subjects were nine male university physical education students between the ages of eighteen and twenty.

The apparatus was basically a smoothly rotating handle modified to facilitate collection of data. The visual cues were controlled by the means of opague ski goggles. The subject's task was to rotate the handle once for information input, store the material for a period of delay, and rotate the handle for information output.

There were four factors of experimental interest: sensory modality with two levels, (visual (V) and kinesthetic (K)) and period of delay with three levels (immediate, 10-second delay, and 10-second delay with an interpolated task (IT)), distance with three levels (30, 60 and 120 degrees) and starting quadrant with three levels (three of the four quadrants).

The specific problems examined in the study were:

1. The effect of distance on V and K storage of information over three periods of delay (immediate, 10-second delay, and 10-second delay with an IT).

2. The effect of starting quadrant on V and K storage of information over the three periods of delay (above).

3. The relationship between the V and K sensory modalities to period of delay (above) using a motor task that varied starting quadrant and distance.

Four hypotheses were formed to help structure this study: The first hypothesis stated that immediate errors were less than or equal to a 10-second delay errors which were both less than a 10-second delay with IT errors. The second hypothesis stated that V performance was superior to K performance. The third hypothesis stated that performance of the 60 degree distance was superior to the 120 degree distance and that the 30 degree distance was superior to both the 60 degree and 120 degree distances. The fourth hypothesis was stated in null form that starting quadrant one's performance equalled starting quadrant two's performance and that starting quadrant three's performance equalled both starting quadrants one and two's performance.

II. CONCLUSIONS

On the basis of the results obtained and within the limitations of the design and technique of data collection, the following conclusions were drawn.

The increase of the distance to be reproduced causes an increase in the amount of error or a decrease in performance accuracy. There was a linear relationship between the amount of error and the logarithm (base two) of the distance.

The recall of visually stored information was superior to the recall of kinesthetically stored information.

One could conclude that starting quadrant had no effect on performance. However, because the technique used for selection of the starting quadrants was questionable, the effect of starting position has been left unanswered. Similarly, the problem of the interpolated tasks leaves the period of delay results debatable, thus no conclusion could be formed.

III. RECOMMENDATION

The results of this and other studies on kinesthesis have been exploratory in nature to date. Further research on the topic must be unified by standardization of the control factors and motor tasks. Hopefully, a rigid operational definition of kinesthesis would evolve. From this point the role of kinesthesis in motor learning and human performance could be evaluated.

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